MICRO 7801

THE BACTERIOLOGICAL WATER QUALITY OF THE STURGEON RIVER AT STURGEON FALLS 1977; EFFECTS OF WASTEWATER FROM THE ABITIBI PAPER MILL

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SUMMARY

The Sturgeon River at Sturgeon Falls was surveyed for bacterial pollution in June and August of 1977. The pattern of results was the same in both surveys. The bacteriological water quality of the river above the dam at Sturgeon Falls was fairly good. Below the dam the water quality was poor and bacterial levels approached and in some cases exceeded the Recreational Criteria for total body contact.

The main input of fecal bacterial was traced to the Abitibi Forest Products Plant which discharged wastes immediately below the Sturgeon Falls. The zone of influence of this pollution was charted all the way to the mouth of the Sturgeon River. The effect on Lake Nipissing was not determined.

Among the bacteria discharged in large numbers from the wood - processing plant were two that are known to be opportunistic pathogens to humans; Klebsiella pneumonia which has been reported in other pulp mill effluents, and Pseudomonas aeruginosa which is often found to be of fecal origin. Evidence was presented to show that fecal bacteria increased in the nutrient- rich wood processing wastes in the Abitibi plant before being discharged to the river.

The sewage treatment plant at Sturgeon Falls discharged a chlorinated effluent with relatively few viable fecal bacteria, and the effect of this on the river cannot be seen under the present polluted conditions.

It was recommended that a cleanup program of the Abitibi wastewater would be beneficial to water quality below Sturgeon Falls. Further work should be undertaken to describe the source and conditions of growth of bacteria in the wood processing plant.

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DESIGN OF THE SURVEYS

Timing:

Measurement of bacterial numbers over five consecutive days at a sampling location provides a reliable number to be taken to arrive at a sound value of the bacterial density. When many river stations are sampled in this manner a reproducible bacteriological picture of the river is obtained.

Two consecutive five-day bacteriological water quality surveys were carried out between June 25 and June 29, and August 10 and August 14, 1977. Data was obtained from samples taken from 40 river locations. Sixteen hundred and fifty bacterial determinations were carried out on these samples. In addition, 231 fecal coliform isolates, and 122 Pseudomonas aeruginosa strains were identified by rapid identification techniques.

Selection of Sampling Locations:

The bacteriological sampling stations were located at some mid-river points, inflows and in areas representative of the various degree of shoreline development found on the river. Samples were taken at 28 shoreline locations and 12 mid-river stations (Figure 1). The samples were taken one meter below the surface, as well as directly from piped effluents. The water quality of the river was obtained above, at, and below the Abitibi Paper Products plant. Samples were taken in clean sterile 500 ml bottles.

Bacterial Tests and Interpretation:

The density of three 'indicator' organisms was determined on each sample. The three indicators, total coliform, fecal coliform and fecal streptococcus bacteria are all indigenous to man and other warm-blooded animals, and are found in the colon and feces in tremendous numbers. Many diseases common to man can be transmitted by feces; consequently, the probability of occurrence of these diseases is highest in areas where the water is contaminated with fecal

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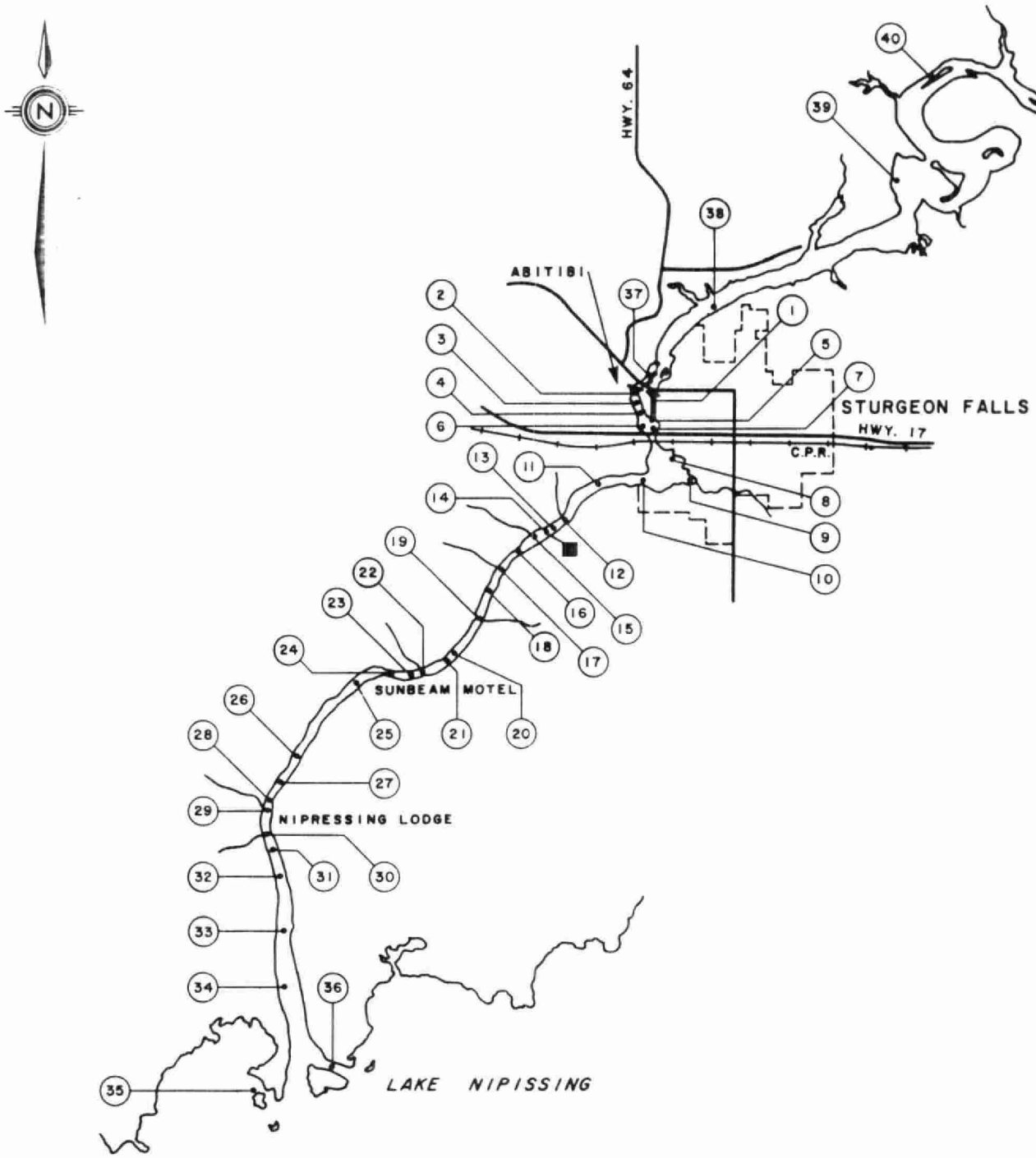
FIGURE 1 - LOCATION OF BACTERIOLOGICAL SAMPLING STATIONS ON THE STURGEON RIVER.



LEGEND

- DAM
- SEWAGE TREATMENT PLANT
- FLOATING LOG-CHAIN BARRIER
- (8) — SAMPLING STATION

1 .5 0 1 KILOMETRES

0 1/2 1 MILES

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material. These indicator organisms in water signify the possible presence of disease causing organisms. The density of heterotrophic bacteria and the opportunistic pathogen Pseudomonas aeruginosa was also obtained. The heterotrophic bacteria were determined from 5 sampling locations, two of which were located upstream (Stations 37 and 40) and three downstream (Stations 6, 20 and 28). Pseudomonas aeruginosa is found largely in the feces of man and may cause disease when encountered in water. Heterotrophic bacteria are found in the greatest numbers in nutrient-rich waters.

The density of these bacteria in water will vary considerably between samples taken at the same station, or at different stations on a river, or if taken at different times, and so the assessment of water quality cannot be determined accurately from a single water sample. Therefore, the bacteriological surveys require many samples to be taken at several river stations over a period of time. The large amount of data obtained is reduced by calculations to meaningful and easily managed statistics.

These data were then evaluated by statistical techniques in the following manner. The geometric mean, the most appropriate central value and variance were calculated for the values of each indicator bacterium and Pseudomonas aeruginosa at every station, providing concise valid data. Statistically significant variations in the bacterial densities between stations, or groups of stations, were determined by a One-Way Analysis of Variance and Barlett's Test of Homogeneity. By these means, the data from each station were tested against that of every other station until all stations with similar geometric mean densities were separated into groups (Group A, B ...).

The group results and those for individual stations were identified by different stippling. Within each stippled area, the group geometric mean applies for each type of bacteria unless otherwise indicated by individual station values.

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The areas of better or worse bacterial densities were defined by the group geometric mean densities, and so any inputs of bacterial contamination, and the area they affect, were identified.

Bacterial Enumeration:

1. Total coliform (TC) bacteria were determined as a count of dark-red colonies with gold metallic sheen grown on a membrane filter (Gelman GN6) with m-Endo LES agar (2).
2. Fecal coliform (FC) bacteria were determined as a count of acid producing yellow to yellowish-green colonies grown on a membrane filter with MacConkey broth at 44.5^{o}C (2).
3. Fecal streptococcus (FS) bacteria were obtained from a count of pink or red colonies grown on a membrane filter with m-Enterococcoccus agar (2).
4. Pseudomonas aeruginosa (PA) were determined as a count of flat, tan to brown colonies grown on a membrane filter with mPA medium (7).
5. Heterotrophic bacteria (HB) were obtained from a total count of colonies from surface inoculated plates of modified Foot and Taylor medium, incubated for seven days at 20^{o}C (4).

Bacterial Identification:

Fecal coliforms were identified using the Enterotube system (Hoffmann-LaRoche), Klebsiella pneumoniae was identified from the fecal coliforms in this manner, Pseudomonas aeruginosa was identified by its action upon Skim Milk and Acetamide agars, along with the oxidase test.

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RESULTS

Water Quality of the River in 1977:

In June and August 1977, the bacteriological water quality of the river above the dam at Sturgeon Falls was good. Below the dam the water quality of the river was poor and bacterial levels approached and, in some cases, greatly exceeded the Recreational Criteria for total body contact which states:

> "Water should be free from pathogens including any bacteria, fungi or virus that may produce enteric disorders or eye, ear, nose, throat and skin infections. Where ingestion is probable, recreational waters can be considered impaired when the coliform (TC), fecal coliform (FC) and/or enterococcus (fecal streptococcus, FS) geometric mean density exceeds 1000, 100 and/or 20 per 100 ml respectively, in a series of at least ten samples per month, ... (3).

The Results of The Spring Survey

In June, the geometric mean bacterial densities for the river above the dam (at the falls) were within the MOE Recreational Criteria with the exception of fecal streptococcus. The bacterial levels were 206 TC, 11 FC, 51 FS and 2 PA per 100 ml (Group A, Figure 2). Below the dam the bacterial levels rose to 2,800 TC, 307 FC, 995 FS and 31 PA per 100 ml, thereby exceeding the MOE Recreational for all parameters (Group B, Figure 2). The increased levels of fecal coliforms and Pseudomonas aeruginosa indicated a large source of fecal bacteria in the vicinity of Sturgeon Falls.

Very poor water quality was found at the main outfall from Abitibi (Station 1). The bacterial densities at this location were 330,000 TC, 168,000 FC, 201,000 FS and 143 PA per 100 ml which exceeded the levels of bacteria found everywhere else on the river. Other outfalls from or near the Abitibi plant

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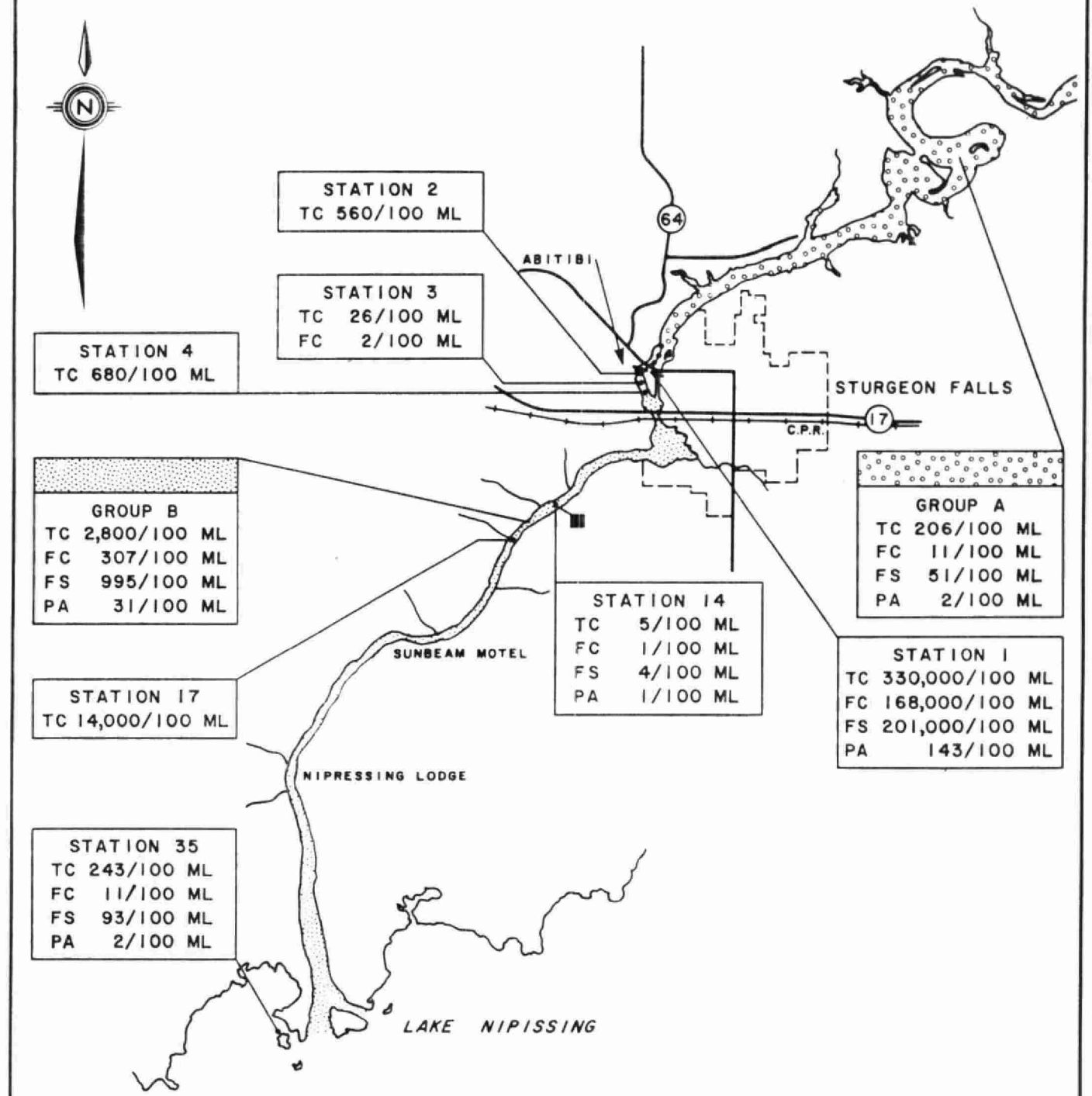
FIGURE 2 - DISTRIBUTION OF BACTERIA FOR THE JUNE 25 TO JUNE 29 SURVEY.



LEGEND

— DAM

— SEWAGE TREATMENT PLANT

— FLOATING LOG-CHAIN BARRIER

GROUP OR STATION	
TC	GM/100 ML
FC	GM/100 ML
FS	GM/100 ML
PA	GM/100 ML

PA - PSEUDOMONAS AERUGINOSA

GM - GEOMETRIC MEAN

1 .5 0 1 KILOMETRES

0 1/2 1 MILES

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(Stations 2, 3 and 4) had low densities of total coliforms which ranged from 26 - 680 TC per 100 ml and a low fecal coliform level of 2 FC per 100 ml at Station 3.

Further downstream the outfall from the sewage treatment plant (STP), Station 14, had low bacterial densities of 5 TC, 1 FC, 4 FS and 1 PA per 100 ml. These low bacterial densities were brought about by chlorination of the STP effluent.

An inflowing stream (Station 17) had elevated total coliform levels of 14,000 TC per 100 ml. Inflowing streams often have higher bacterial densities than the receiving waters as they may carry materials washed from soil, decaying matter and, if present, animal and human wastes into the river.

The bacterial densities were reduced where the Sturgeon River flowed into Lake Nipissing. At Station 35, bacterial densities of 243 TC, 11 FC, 93 FS and 2 PA per 100 ml were found and the reduction in the previous high bacterial densities was likely due to dilution of the river water in the lake.

The geometric mean density of aerobic heterotrophic bacteria upstream from Sturgeon Falls (Station 37 and 40) was 935 HB per 1.0 ml, whereas downstream the levels of heterotrophic bacteria rose significantly to 7,730 HB per 1.0 ml at Station 6 and to 58,600 HB per 1.0 ml further downstream at Stations 20 and 28 (Table 1). The large progressive increases in heterotrophic bacterial densities below the falls may indicate growth of bacteria in response to the higher nutrient levels in these waters.

The types of fecal coliforms isolated from the lower section of the river (Station 26) were identified. The results showed that 27% were Escherichia coli, a bacterium that is found in feces. Klebsiella pneumoniae made up 69% of the fecal coliforms. This bacterium is an opportunistic pathogen to humans. It is found in relatively low numbers in feces but has been found in high numbers in pulp-mill waste and in unchlorinated effluent from sewage treatment plants. Further work was performed later in the summer to pinpoint the source of this bacterium.

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TABLE 1

Geometric Mean Densities (per 1.0 ml) of Heterotrophic Bacteria

	Upstream from Sturgeon Falls (Stations 37 & 40)	Station 6	t- Test	Downstream from Sturgeon Falls (Stations 20 & 28)	t- Test
June	935	7,730	*	58,600	*
August	1,980	15,100	*	67,500	*

* Mean densities of Heterotrophic Bacteria at different locations were found to be significantly different by a t - test (95% level of confidence).

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The Results of The Summer Survey

In August, the geometric mean bactarial densities for the river above the dam were 130 TC, 4 FC, 39 FS and 1 PA per 100 ml (Group A, Figure 3). This level of water quality would be considered satisfactory for river water, however, the fecal streptococcus levels exceeded the MOE recreational criteria, and indicated a low level of contamination probably of animal or of stormwater origin. The lower part of the river (where the water from Abitibi rejoins the water that flows over the dam) showed increased bacterial densities of 815 TC, 48 FC, 445 FS and 18 PA per 100 ml (Group B, Figure 3). The only large input of bacteria in this location was from the main outfall from Abitibi (Station 1) which discharged water containing 119,000 TC, 4,900 FC, 10,000 FS and 5,500 PA per 100 ml. Smaller densities of the fecal indicator bacteria were found in the other outfalls near the Abitibi plant; bacterial densities 277 TC and 6 PA per 100 ml; 63 TC, 12 FC and 7 PA per 100 ml; and 11 TC, 108 FS and 3 PA per 100 ml were found at Stations 2, 3 and 4 respectively.

Further downstream the bacterial densities rose to 4,800 TC, 48 FC, 445 FS and 82 PA per 100 ml (Group C, Figure 3). The increase in density of total coliforms, fecal streptococci and P. aeruginosa was possibly due to growth of these bacteria in the nutrient-rich river water. The sewage treatment plant outfall (Station 14) contained 15 TC,1 FC, 24 FS and 4 PA per 100 ml.

As in the spring, the bacterial densities were reduced where the Sturgeon River flowed into Lake Nipissing. At Station 35, the densities of total coliforms and Pseudomonas aeruginosa were reduced by dilution in the lakewater to 952 TC and 2 PA per 100 ml.

The geometric mean density of the aerobic heterotrophic bacteria was 1,980 HB per ml upstream from Sturgeon Falls which increased to 15,100 HB per ml at Station 6. Further down the river heterotrophic bacterial densites rose to 67,500 HB per ml. In agreement with the June survey, the progressively higher

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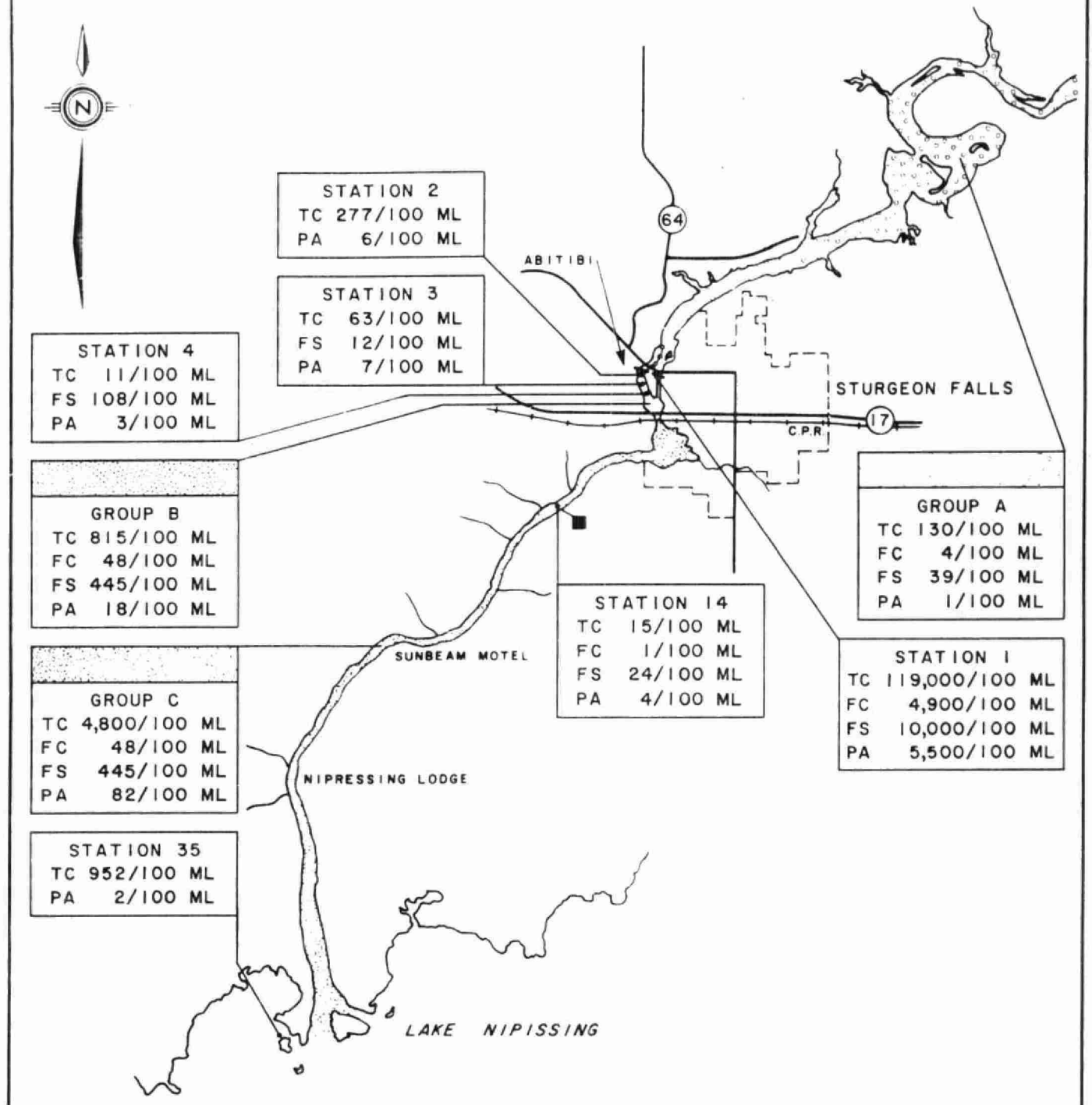
FIGURE 3 - DISTRIBUTION OF BACTERIA FOR THE AUGUST 10 TO AUGUST 14 SURVEY.



LEGEND

— DAM

■ — SEWAGE TREATMENT PLANT

•••• — FLOATING LOG-CHAIN BARRIER

GROUP OR STATION
TC GM/100 ML
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PA - PSEUDOMONAS AERUGINOSA
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heterotrophic densities downstream indicated increased nutrient levels and possibly subsequent growth of bacteria in the river (Table 1).

Geometric mean densities of each parameter were calculated for each sampling location on the river and displayed in order, following the downstream flow of the river. The large input of bacteria from the Abitibi outfall was very obvious in both spring and summer (Figures 4 and 5). In the summer, P. aeruginosa and fecal streptococci appeared to grow in the river. For example, the densities of P. aeruginosa increased progressively downstream, from Station 5 to Station 13, but slowly decreased thereafter until the river discharged into Lake Nipissing (Station 35) where the decrease was more rapid (Figure 5).

The evidence of fecal pollution obtained from the bacteriological surveys made it necessary to confirm the identity of some of the Pseudomonas aeruginosa and fecal coliforms isolated from the river. Between 96-98% of the Pseudomonas aeruginosa colonies were confirmed as Pseudomonas aeruginosa. This high rate of confirmation of Pseudomonas aeruginosa applied to bacteria isolated in the Abitibi plant, from outfalls and from the river (Table 2). All of the fecal coliforms isolated above the dam at the falls were identified as E. coli. The fecal coliforms isolated below the dam showed greater species diversity which resulted in the isolation of large numbers of thermotolerant K. pneumoniae and oxidase positive bacteria. The source of these bacteria was found inside the Abitibi plant (Table 3).

Previous River Sampling:

The Sturgeon River above and below Sturgeon Falls has been sampled before by the Ministry of the Environment Water Resources Branch (9). This data is summarized in Table 4. Bacterial densities in the river were significantly higher downstream from Sturgeon Falls than upstream at Crystal Falls. This indicated a major input of fecal bacteria between these two locations which has now been traced to the Abitibi Forest Products Plant.

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FIGURE 4 - GEOMETRIC MEAN LEVELS OF FECAL COLIFORMS, FECAL STREPTOCOCCUS AND PSEUDOMONAS AERUGINOSA VS STATIONS ON THE STURGEON RIVER DURING THE JUNE 25-29, 1977 SURVEY.

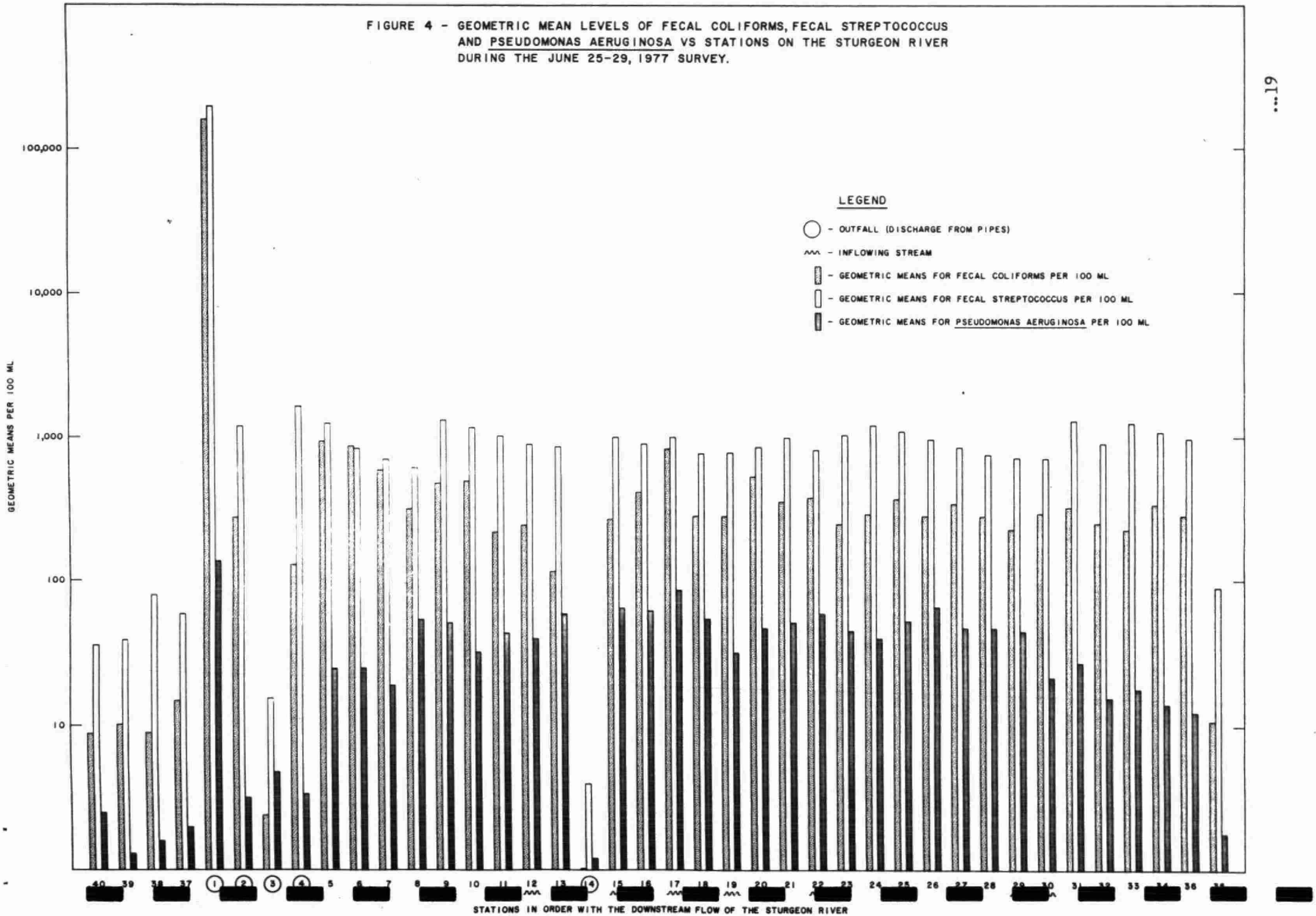

FIGURE 5 - GEOMETRIC MEAN LEVELS OF FECAL COLIFORMS, FECAL STREPTOCOCCUS AND PSEUDOMONAS AERUGINOSA VS STATIONS ON THE STURGEON RIVER DURING THE AUGUST 10-14, 1977 SURVEY.

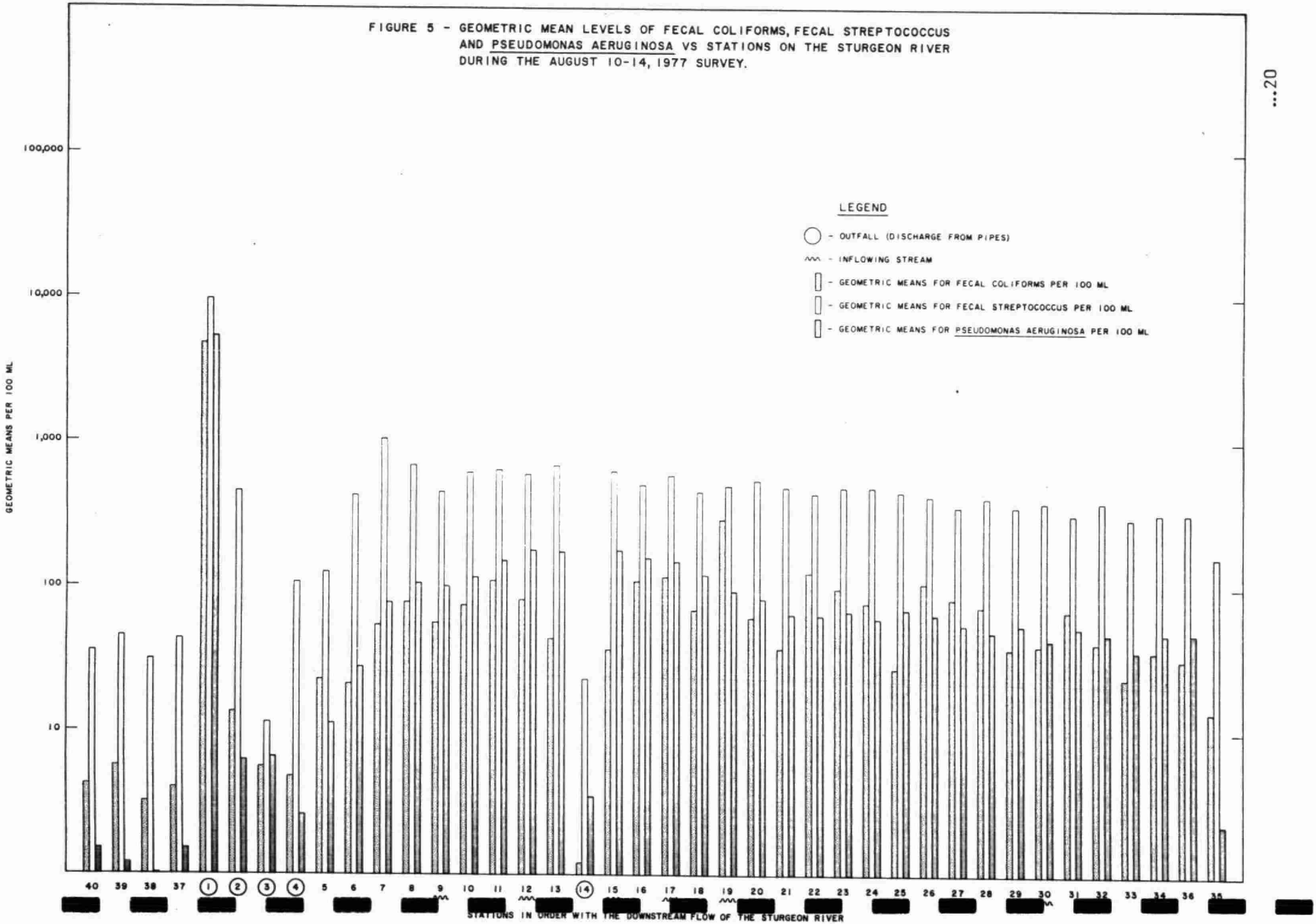

TABLE 2

Confirmation of Identification of Pseudomonas aeruginosa Isolated During the Sturgeon River Survey

Location	Number of Colonies	Identification	% P. aeruginosa
Inside Abitibi Plants (4 locations)	46/47	P. aeruginosa	97.9
	1/47	No Identification	--
Abitibi Outfalls (Stations 1 and 3)	51/53	P. aeruginosa	96.2
	2/53	No Identification	--
River below the dam	21/22	P. aeruginosa	95.5
	1/22	No Identification	--
Total	118/122	P.aeruginosa	96.7

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TABLE 3

Identification of Fecal Coliforms Isolated From Four Locations During the Sturgeon River Survey

Location	% Species Composition †					
	E. Coli	K. Pneumoniae	E. Cloacae	E. Agglomerans	Oxidase Positive	No Identification Available
Upstream from Abitibi	100.0	-	-	-	-	-
Inside * the Abibiti Plant	28.0	56.0	12.0	-	4.0	-
Abitibi Main Outfall	3.7	59.2	-	3.7	33.3	-
Downstream From Abitibi	13.2	54.7	3.8	-	16.9	11.3

* Samples were taken from several sewers containing industrial wastes but where sanitary sewage was absent.

† Analysis of 180 Isolated Fecal Coliforms.

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TABLE 4

Confirmation Evidence From Earlier Water Quality Monitoring Surveys

Geometric Mean (per 100 ml) of All Annual Data

	Above Abitibi (Crystal Falls)			Below Abitibi (Downstream from Sturgeon Falls)		
Year of Survey	TC	FC	FS	TC	FC	FS
1970	21	-	-	2400*	-	-
1971	76	-	-	4430*	-	-
1972	24	2	1	3100*	385*	57*
1973	1040	18	3	2600	83	81*
1974	74	5	5	1600*	76	97
Overall	65	5	2	2920*	154*	73*

* A t-test (95% level) indicated that the bacterial levels in the river below Sturgeon Falls were significantly higher than those above the falls.

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The bacterial densities for Crystal Falls (i.e. above Sturgeon Falls) showed a significant increase in 1973. This indicated an intermittant source of fecal pollution at Crystal Falls. This source of pollution appeared to be much smaller in effect than the pollution source at Sturgeon Falls.

DISCUSSION

Description of The Problem

The determination of fecal indicator bacteria in the Sturgeon River (Figures 2 and 3) resulted in an assessment of fairly good water quality above the dam at the Sturgeon Falls which then contrasted with very poor water quality below the dam. The cause of degradation of the water quality was traced to pollution from the Abitibi Forest Products Plant. The data on the distribution of fecal bacteria in August, for greater clarity, was tabulated to illustrate only the effect on the river caused by the main Abitibi outfall (Table 5). The pollution appeared at first to be only fecal in nature but the situation was found to be more complex.

Identification of Bacteria Isolated From Industrial Wastewater

The types of fecal coliforms isolated from the river below the falls resembled those that were isolated from the plant and from the plant outfall. The types of fecal coliforms isolated from the river above the falls were not similar to those isolated below the falls or from the plant. This information further confirmed the conclusion made from the quantitative data that the source of the pollution in the river was the Abitibi paper products plant.

The dominant fecal coliform from the Abitibi plant was *K. pneumoniae*, a bacterium which is recognized as an opportunistic pathogen causing

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TABLE 5

BACTERIAL DENSITIES (PER 100 ML) IN AUGUST IN THE GREATER BODY OF WATER ABOVE AND BELOW THE MAIN ABITIBI OUTFALL

Water Quality Parameter	Upstream from Abitibi	Main Outfall at Abitibi	Downstream from Abitibi
Total Coliform	130	119,000	815
Fecal Coliform	4	4,900	48
Fecal Streptococcus	39	10,000	445
P. aeruginosa	1	5,000	82
Heterotrophic Bacteria	198,000	-	6,750,000

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respiratory and other infections. Low densities of K. pneumoniae are commonly found in nature and they are found in the bark of trees and from there it would be carried into wood-processing plants. This opportunistic pathogenic bacterium has been isolated before from pulp-mill effluents (5).

Another opportunistic pathogenic bacterium, P. aeruginosa, was found in great numbers in the Abitibi plant effluent. P. aeruginosa may cause ear and eye infection in bathers and is considered an undesirable bacterium in recreational waters. The primary source of P. aeruginosa is considered to be sewage or nutrient-rich contaminated water.

Growth of Fecal Bacteria In Abitibi Wastewater

The source of P. aeruginosa in the Abitibi plant was probably river water brought into the plant for processing purposes. The initially low number of P. aeruginosa could increase due to growth on the nutrients extracted from the wood during the processing. The sewers containing sanitary waste were tested with dyes by the MOE for cross-connections with the processing side of the plant. The results indicated that the water used for wood-processing was not contaminated by sanitary waste originating in the Abitibi plant. It was concluded that P. aeruginosa in small numbers was brought into the plant in river water and that the larger numbers in the effluent came about through growth in the nutrient-rich plant processing waters.

A similar argument can be used to show that total coliform and fecal streptococci were brought into the plant in river water and subsequently grew in the nutrient-rich industrial wastes.

E. coli was discharged into the river from the Abitibi plant at an approximate concentration of 180/100 ml. It is considered that the sole source of E. coli in the environment is feces or sewage-contaminated water. The dye tests of the plant sanitary sewers indicated that the plant outfall was not contaminated

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directly by sewage. Some E. coli, 4/100 ml, was brought into the plant in river water and the increase in numbers may have been brought about by growth in the nutrient-rich wood-processing wastes. This conclusion depends on the accuracy of the dye tests of the plant sanitary sewers. It was an important and unexpected result for it illustrated one of the rare occasions when E. coli grew in the environment. Consequently, it is recommended that the results of the dye tests be confirmed.

An Alternative Hypothesis For Growth of Bacteria in The Abitibi Plant

The primary conclusion of our surveys was that large numbers of fecal bacteria from the Abitibi plant were discharged into the Sturgeon River causing serious water quality deterioration of the river water. It is only of secondary interest whether or not these bacteria grow in the mill wastewater. Another possibility is that the bacteria grew on or under the bark of trees during storage in the river or in the mill prior to pulping. The increase in numbers would be brought about by mechanical disintegration of the bacterial growths. In support of the bacterial growth hyphothesis, it was observed that numbers of total coliforms and K. pneumoniae increased markedly during the secondary treatment of pulp-mill wastewater. It was also observed that K. pneumoniae was able to grow rapidly in sterile wastewater from a pulp-mill (6).

Growth or 'Regrowth' of Bacteria In The River

The numbers of bacteria in the river increased below the Abitibi outfall (Figure 5) and the increases were initially attributed to growth of bacteria in the river. However, the BOD of the river water was not very high (see comparison report by J. Myslik) and the results may be better explained by the process of 'regrowth'.

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Injured bacteria are unable to grow in the selective media used for water microbiology. As the injured portion of a population of bacteria recover, the number of colonies which appear on the selective medium increases without real bacterial growth in the river water. This phenomenon mimics growth and is called 'regrowth'. The injured bacteria in the river population could be heat-injured and may be produced by the hot process used in the wood-processing plant. It was concluded that the increases in bacterial densities in the river below the Abitibi outfall may be accounted for by growth or 'regrowth'.

Effect of The Sewage Treatment Plant On The Water Quality of The River

It can be seen that following these increases in bacterial numbers in the river, the maximum densities of bacteria and so the maximum of water quality deterioration, was achieved before the sewage treatment plant outfall was reached (Figure 5). The sewage treatment plant did not appear to have an effect on the river water quality, however, an effect could have been obscured by the poor water quality of the river at the point of effluent discharge. This is considered unlikely since the reported operating record of the STP was good, and the quality of disinfected effluent samples were similar to samples taken in this survey (8).

Conclusions

The zone of influence in the river of the pollution from Abitibi was from Sturgeon Falls to the mouth of the Sturgeon River. The size of the mixing zone in Lake Nipissing was not determined in 1977 due to the size and cost of such a study.

The effect of pulp and paper waste on the microbiology of receiving waters is a fairly recent topic of study. Microbiological parameters were not used to describe the predicted environmental impact of pulp and paper waste in recent Ministry documents (1). Those interested in this topic can find up-to-date information in a recent review article (10).

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Microbiological studies that have been carried out over many years at Sturgeon Falls have documented that the pollution problem in the Sturgeon River is not a new one. The studies in 1977 confirmed the existence of pollution and further described the type of pollution and its source. Corrective action is desirable and would bring about improvement in water quality of the Sturgeon River below Sturgeon Falls.

The problem of pollution is not isolated to the plant on the Sturgeon River since fecal pollution has been documented downstream from the Abitibi Paper Company at Smooth Rock on the Mattagami River (9). Other paper companies have been shown to cause bacterial pollution, for example, the Spruce Falls Paper Company on the Kapuskasing River (9).

SPECIAL RECOMMENDATIONS

1) Further tests be carried out to confirm that sanitary waste from the Abitibi plant does not contaminate the pulp and paper processing wastes.
2) That studies be carried out in the Abitibi plant to describe more fully the conditions available for bacterial growth in the pulp and paper wastes.
3) That investigation be carried out on the wastewater from other Pulp and Paper Plants where high levels of pollution parameters have been indicated.

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